World Applied Sciences Journal 2 (1): 40-44, 2007
ISSN 1818-4952

Application of *Platanus orientalis* Leaves in Removal of Cadmium from Aqueous Solution

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Abstract: Removal of cadmium from aqueous solution was studied; using *platanus orientalis* leaves (POL) and their ash in 2006 in Iran. Bach adsorption experiments were performed as a function of solute concentration, contact time, pH and ironic strength for the experiment. The effect of Ca^{2+}, Mg^{2+}, Na and K^{+} on adsorption was then examined. The effect of this adsorbent on COD in aqueous solution showed that 1 g l^{-1} of adsorbent caused increase of 110 and 76 mg l^{-1} COD in deionized water in 120 min for POL and its ash. The maximum removal took place in the pH range of 7 contact time in 60 minutes and initial concentration of 2 mg l^{-1}. The cadmium sorption followed both the Longmuir and Freundlich's equation isotherms. The study showed POL ash was more favorable than living ones as well as in removing cadmium from the aqueous solution. The adsorbent capacity was also studied. The adsorbent capacity and the adsorbent intensity values showed that *Platanus orientalis* leaves, a non-conventional adsorbent is efficient in removing Cd from aqueous solution. The adsorption data fitted well into Freundlich isotherm.

Key words: *Platanus orientalis* leaves · aqueous solution · ash · cadmium removal

INTRODUCTION

Nowadays the contamination of water is not the concern of only the scientific community. In recent years a general environmental awareness has developed that is related to the actual knowledge and control of water pollution. Metal ions in water can occur naturally from leaching of ore deposits and from anthropogenic sources, which include mainly industrial effluents and solid waste disposal. Due to high development of industrial activity in recent years, the levels of heavy metals in water system have substantially increased over time [1]. This makes it necessary to develop methods that allow one to detect, quantify and remove these heavy metals from the effluent waters [2]. Among these metal ions, ions of Cd, Zn, Hg, Pb, Cr, Cu, etc. gain importance due to their high toxic nature even at very low concentrations. Various methods are available to isolate and remove these heavy metals from the environment. Adsorption is one of the easiest, safe and cost effective methods, being widely used in effluent treatment processes [3]. Adsorbents like, charcoal, clay, fuller's earth, saw dust, rice husk, coir pith etc. are commonly used adsorbents. In the present study, cashew hull which is a solid waste from cashew industries was subjected to adsorption of heavy metals to study its potentiality as an adsorbent [4]. Treatment of cadmium contaminated water is similar to that of many metal contaminated effluents. There are several methods to treat the metal contaminated effluent such as precipitation, Ion exchange, adsorption, etc., but the selection of the treatment methods is based on the concentration of waste and the cost of treatment [5-8]. In the last few years, adsorption has been shown to be an economically feasible alternative method for removing trace metal from wastewater and water supplies [9-11]. Activated carbon has been the most used adsorbent; nevertheless it is relatively expensive of individual sorbents varies depending on the degree of processing required and local availability [12].

In general, a sorbent can be assumed as "low cost" it is requires little processing, is abundant in nature, or is by product or waste material from another industry [12]. Activated carbon from cheap and readily available sources such as coal, coke, peat wood, rice husk and tree leaves may be successfully employed for the removal of cadmium and other toxic heavy metals from aqueous solution [13-15]. Other adsorbents such as a wood charcoal, red mud, sun flower stalks, petioles felt-sheath and rice husk have also been used for the adsorption of cadmium [11, 16-18]. The objective of this paper is to

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explore the feasibility of *Platanus orientalis* leaves and its ash as an adsorbent for removal of cadmium from aqueous solution. The parameters that effect on adsorption such as initial cadmium concentration, contact time, pH and the effect of Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} were investigated and so in this study the effect of this adsorbent on COD in aqueous solution were investigated.

MATERIALS AND METHODS

Platanus orientalis Leaves used was obtained from the various Tehran parks, in the polluted city in the World (Plate 1). The dominant species for all of the samples of Tehran plane (Plate 1) is a deciduous tree, frequently planted in the Tehran city parks as well as the streets yards and refuge, as it is able to withstand urban conditions. It is a cultivated hybrid species, with traits common to the native oriental plane-tree (*Platanus orientalis*).

For the wet digestion, the POL was washed with deionized water and then laid down to be dried. Dried leaves were then ground with electronic grinder and were then sieved with 60-70 mesh (0.20-0.3 mm). For the ash digestion, the leaf was dried in an oven at 80°C to allow to be determined prior to analysis. The dried leaf was then stored in desiccator's apparatus and weighed. The POL ash obtained from burning of POL in electrical oven at 550°C for 30 min. Adsorption of cadmium in aqueous solution on POL and its ash were examined by optimizing various physicochemical parameters such as: pH, contact time, concentration of Cd and the effect of light metals (Ca^{2+}, mg^{2+}, Na^{+} and K^{+}) which were studied. Stock solution of cadmium (1000 mg l^{-1}) was prepared by dissolving cadmium nitrate in distilled water. The concentration range of cadmium prepared from stock solution varied between 2 to10 mg l^{-1} for both POL and its ash. Before mixing the adsorbent, the pH of each last solution was adjusted with the required value with diluted and concentrated H_2SO_4 and NaOH solution, respectively. The Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} solution were prepared by its salt in concentration of 2 mol l^{-1}. The experiments were carried out in the batch modes for the measurement of adsorption capacities. Each cadmium solution was placed in 1000 ml beaker and known amount of adsorbents were added to each beaker. The beakers were agitated on jar test equipment at a 300 rpm constant mixing rate for 30-240 min to ensure equilibrium was reached.

Finally the suitability of the Freundlich and langmuir adsorption models to the equilibrium data were investigated for cadmium sorbent system. A duplicate

Plate 1: Tehran Plane Leaf

analyzed for every sample to track experimental error and show capability of reproducing results. For quality control purpose, deionized water digested and analyzed with every sample group to track and possible contamination source. The residual cadmium was analyzed through atomic spectrometry using an ALPH-4-flams atomic absorption spectrophotometer, using an acetylene air flame according to Standard Methods [19].

RESULTS AND DISCUSSION

At this experiment, the adsorption of cadmium increased with increasing contact time and became almost constant after 60 min for POL and 60 min for its ash (Fig. 1).

These results also indicate that the sorption process could be considered very fast because of the largest amount of Cd attached to sorbent within the first 60 min of adsorption.

The Freundlich isotherm is the earliest known relationship describing the adsorption equation and often expressed as equation 1:

$$q_e = \frac{(C_\circ - C_e)V}{m} \quad (1)$$

Where:

q_e = The adsorption density/mg of adsorbate per g of adsorbent;

Ce = The concentration of adsorb ate in solution mg l^{-1};

C_e = Final equilibrium concentration of adsorbate after absorption has occurred, mg l^{-1}

V = Volume of liquid in the reactor, (L)

M = mass of adsorbent, (g)

Experiments concerning the effect of pH on the sorption were carried out with the range of pH that was not influenced by the metal precipitation, as metal hydroxide. The suitable pH ranges for cadmium was performed for the pH range variations of 3-9.

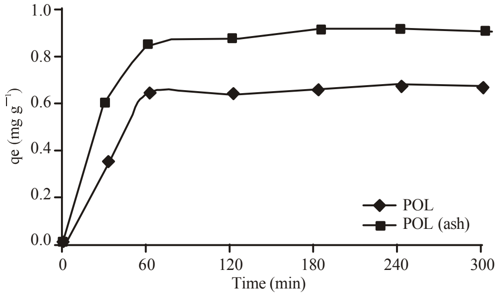

Fig. 1: Effect of contact time on the removal of Cd by POL and its ash (Adsorbent dosage = 2 mg l^{-1} Cd concentration = 2 mg l^{-1})

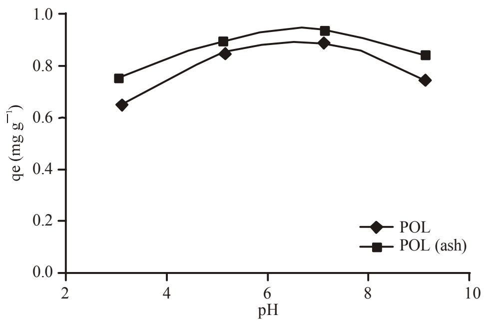

Fig. 2: Effect of pH on the removal of cadmium by POL and its ash (Adsorbent dosage = 2 g l^{-1} Cd concentration = 2 mg l^{-1})

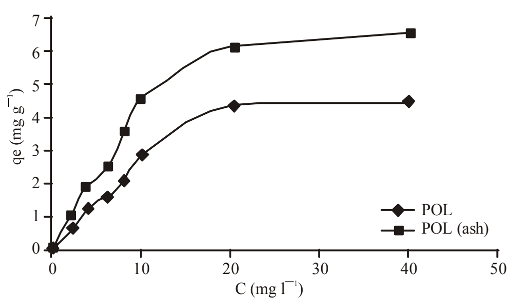

Fig. 3: Effect of Cd concentration on the removal of cadmium by POL and its ash (Adsorbent dosage = 2g l^{-1} pH=7, T=24°C, 300 rpm, 120 min)

Figure 2 shows that in most cases, the removal increased steadily with pH. Adsorption of metal cation on adsorbent depends upon the nature of adsorbent surface and species distribution of the metal cation. Surface distribution mainly depends on the pH of the system [16].

The percent of adsorption for cadmium ion decreased with the decrease in pH, because protons compete with metal ion for sorption sites on the adsorbent surface as

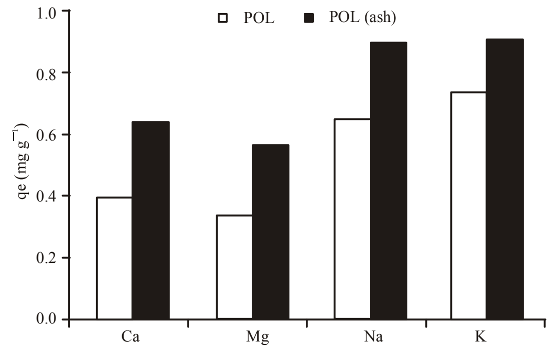

Fig. 4: The effect of light metals on adsorption capacity (Cd = 2 mg l^{-1} and 2 mol l^{-1} Ca, Mg, Na, K)

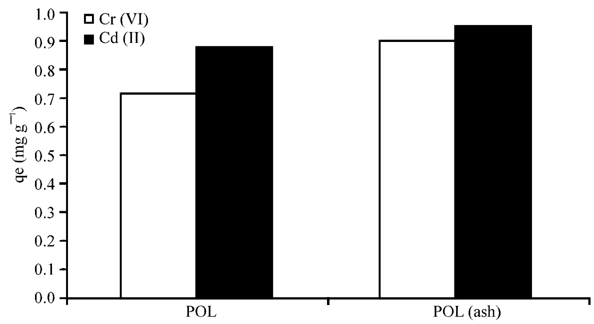

Fig. 5: Simultaneous adsorption of Cd (II) and Cr (VI) ions was studied, using a medium that contained 2 mg l^{-1} of each metal ion

well as the concomitant decrease of negative charge of the same surface. It has been reported that precipitation of cadmium starts at pH 8.3 [8, 16].

The effect of initial metal Ion concentration on the adsorption capacity of POL and its ash was studied under optimum conditions (pH = 7, T = 24-25). Adsorption of cadmium on POL and its ash increased with increasing initial concentration of Cd. These results may be explained by an increase in the number of metal ions competing for the available binding sites in the adsorbent for complexation of Cd ion at higher concentration levels. These results are shown in Fig. 3.

The effect of light metals on adsorption were studied and shown that these Ions can disturb to adsorption of heavy metals on any adsorbent.Ca^{+2} and Mg^{+2} have more effect than Na^{+} and K^{+} in decreasing of q_e for Cd adsorption. The effect of these metals on adsorption is shown in Fig. 4.

Simultaneous adsorption of Cd and Cr (VI) ions was applied, using a medium that contained 2 mg l^{-1} of each metal Ion.

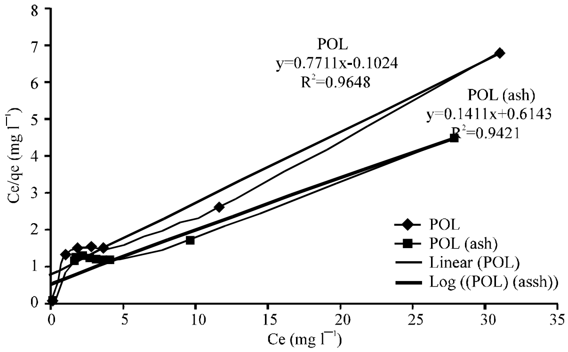

Fig. 6: The linearized Longmuir adsorption isotherm for Cd by POL and its ash

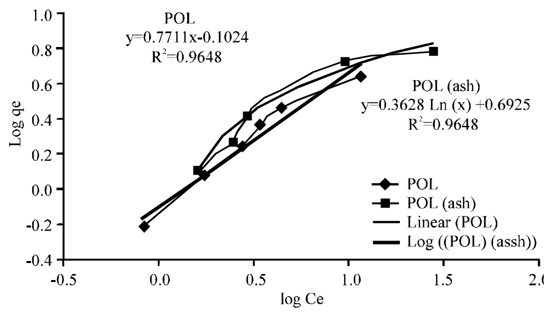

Fig. 7: The linearized Freundlich adsorption isotherm for Cd by POL and its ash

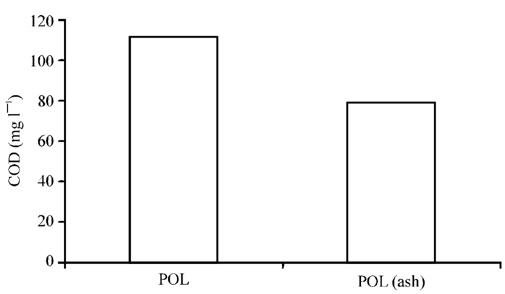

Fig. 8: The effect of 2 g l^{-1} POL and its ash on increase COD (mg l^{-1}) (120 min, pH=7, T= 24°C)

Figure 5, shows that this adsorbent was more efficient for removed of Cd (II) Than Cr (VI).

Two models, Lngmuir and Freundlich equation, were used to determine adsorption of cadmium on to POL and its ash. Isotherm studies were than carried out as described in our earlier paper [11]. The Frenudlich isotherm was also used to explain observed phenomena. K and n values were calculator from the intercept and slope of the POL and found to be R^2 0.9648 for POL and R^2 0.9727 for its ash.

Table 1: Parameters of Freundlich and Langmuir isotherm models

	Langmuir constants			Freundlich constants		
Isotherms	K	b	R^2	Q°	1/n	R^2
POL	20.20	0.0495	0.9617	58.1	0.7711	0.9648
POL (ash)	30.86	0.0324	0.9421	27.4	0.5336	0.9727

The Freundlich isotherm is obeyed better than the langmuir isotherm as is evident from the values of regression coefficient in Table 1. The results are given in Figs. 6 & 7, similar results were reported by Alavi *et al*., [20].

The adsorption capacity (Q°) and energy of adsorption (b) were determined from the slope and intercept of Longmuir plot. The effect of these adsorbents on COD in aqueous were studied. Fig. 8 shows that 2 g l^{-1} adsorbent causes increase 110 and 76 mg l^{-1} COD in Deionizd water after120 min for POL and its ash. This is favorable for biological treatment in industrial Wastewater treatment plant after chemical treatment.

CONCLUSIONS

Tree leaves can be used in the waste water treatment process for the removal of metal Ions. Removal efficiency of cadmium is grater than 85%.The adsorption of metal Ion on tree leaves (POL) Reached equilibrium in 60 min, pH=7 and initial concentration 2 mg l^{-1}. The Freundlich isotherm is followed better than the langmuir isotherm with $R^2$0.96 for POL and 0.97 for POL (ash). POL that used as adsorbent in aqueous solution may be caused increasing COD in the solution.

Platanus orientalis leaves as a natural waste is cheap and available in abundance. The maximum adsorption of Cd metal ions from its dilute solution is observed with the plate tree waste. At a pH of about 8-10 the adsorption was found to be maximum by both forms of the adsorbent material. Around 99% removal efficiency was observed within 3 hrs of contact time by adsorbent that was carbonized. Again at normal temperature range adsorption phenomena were found to be favorable by both forms of the adsorbent and comparatively high in case of carbonized form. Hence, to remove heavy metals like cadmium from industrial wastewater, carbonized waste can be effectively used in adsorption processes.

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